THE EFFECTS OF COPPER-ZINC INTERACTIONS ON YIELD AND YIELD COMPONENTS IN SOILLESS GROWN BEANS (*PHASEOLUS VULGARIS* L.)

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Abstract. This research was conducted under the ecological conditions of Van-Gevaş, Turkey in 2015 and 2016 in three replications according to the Random Parcel Trial Pattern. This study is a flowerpotting trial investigating the effects of copper (Cu) and zinc (Zn) doses applied in increasing amounts to the bean plant grown in the hydroponic system. Four different copper doses (0-200-400-800 mg Cu kg^{-1}) and four different zinc doses (0-2.5-5.0-10.0 mg Zn kg^{-1}) were applied. This study was conducted in drybean varieties on different doses and interactions of Cu and Zn; characteristics such as plant height, number of pods in the plant, number of branches, grain yield in the plant, harvest index and protein ratio were examined. According to the results of the research, while the of 400 mg kg^{-1} Cu and 5.0 mg kg^{-1} Zn dose applied to Yakutiye-98 variety in the first year increased the seed yield (36.32 g $plant^{-1}$) in the plant; in the second year, 200 mg kg^{-1} Cu applied to Yakutiye-98 variety and 5.0 mg kg^{-1} Zn increased the yield (28.45 g $plant^{-1}$). In general copper-zinc interaction; Co-administration of Cu and Zn doses led to increases in yield and yield parameters of bean varieties compared to the separate administration of these doses and was found statistically significant at 1% level.
Keywords: *dry beans, hydroponics, copper, zinc, fertilizer, grain yield*

Introduction

High content of protein in the composition of grains between 22-30% is sufficient by carbohydrates; bean is an important legume plant as it is rich in potassium, calcium, magnesium and phosphorus and also has various vitamins. It is in the first place among legumes in terms of cultivation and production in the world. Dry and fresh consumption of bean is very common. Around 29 million hectares of land is cultivated in the world. The total production is 23 million tons and the yield per hectare is 800 kg (FAO, 2017). In Turkey, bean cultivation area is 848 thousand ha, 220 thousand tons of production and 2590.00 kg ha^{-1} yield is obtained (TUİK, 2018).

As the world population increases rapidly, food consumption is increasing accordingly. This brings about an urgent need for increasing the production together with the need for vegetable protein sources. In order to increase production in existing agricultural areas, grain yield per unit area should be increased. For this reason, it is very important to apply the macro and micro nutrients in sufficient doses considering the interactions with each other as well as technical agricultural practices.

Copper (Cu) and zinc (Zn) are absolutely essential micro nutrients for plants. However, although it is necessary for the life of living things, high doses cause toxic effects on plants and other living things. Although high concentrations of Cu and Zn is toxic, they are part of molecules that play a key role in photo-synthetic electron transport and enzyme activation (Raven et al., 1999).

Copper is a micro nutrient in plants and it is required for respiration, protein synthesis and chlorophyll production. Indeed, it is very effective in protein and carbohydrate

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metabolism. It is an important trace element due to its role in carbohydrate and lipid metabolism through influencing enzyme activity in plants (Kacar and Katkat, 2006). Activation and electron transfer of many oxidase enzymes are carried out by copper (Cu). In particular, the role of copper in the symbiotic nitrogen fixation in legume plants as the subject to this study is important (McCauley et al., 2009). In addition, Cu is an effective element in plant resistance against fungal diseases and in controlling plant moisture (Plaster, 1992).

Copper is present in the soil attached to organic materials, manganese (Mn) and iron (Fe) oxides. As a matter of fact, copper deficiency can be seen in soils rich in organic matter and ready pit soils containing more than 50% organic matter because organic matter holds copper very strongly. In addition, silicates contain copper, which changes and dissolves in weak amounts. Washing of sandy soils also causes copper deficiency. In the absence of copper in the young leaves of plants, chlorosis necrosis such as jaundice is seen, development is stunted, maturation is late and sometimes due to the excess color matter the coffee color symptoms are detected. However, in copper deficiency, plants are particularly vulnerable to fungal diseases caused by fungi. Carbohydrate content in Cu deficiency is very low in the plant. In addition, it was found that the nodule formation in legume plants was interrupted and a small amount of N was fixed (McCauley et al., 2009; Bolat and Kara, 2017).

Copper concentration in clean soils that are not polluted in nature varies between 2-40 ppm, while in dirty soils this value can increase up to 1000 ppm (Sönmez et al., 2006a). Toxic effects occur when the amount of copper in the soil is high and it is difficult for plants to take iron up. Therefore, symptoms of chlorosis appear to be iron deficiency. Another disadvantage of the excess copper in plants is the slowdown of root and shoot development. Also, it's excess in the soil affects the uptake of molybdenum negatively (Bolat and Kara, 2017).

If the amount of copper (Cu) in the dry matter weight of the plant is more than 15-30 mg Cu kg^{-1} toxic effects occur. Copper toxicity in the plant generally occurs in the root region and causes some degradation of the plant's physiological properties such as protein synthesis, photosynthesis, respiration, ion exchange and cell membrane structure (Sossé et al., 2004).

Heavy metal pollution is generally seen in soils with physical, chemical and biological degradation. Copper pollution is caused by natural disasters such as earthquakes, volcanic eruptions and floods as well as anthropogenic activities such as industrial, urban, mining and pesticide use in agriculture and the use of sewage wastes as fertilizers (Karaca and Turgay, 2012; Dağhan and Öztürk, 2015). It is known that copper fertilizers, copper-containing fungicides and pesticides are used more and more widely than necessary in recent years especially against the fungal factors that are defective in agricultural areas. As a matter of fact, it has been reported that Cu content is close to the critical toxicity limit in the Mediterranean Region soils of Turkey and Cu content is above the critical limit in 8% of greenhouse soils (Kaplan, 1999).

Zinc (Zn) plays a role in the metabolism of certain hormones such as auxin, which provides the formation of shoots, and it is also important for the activity of various enzymes that occur in the plant (Marschner, 1997; Kaya et al., 2018). Zinc is one of the micro nutrients that is essential for plants in small amounts.The effect of zinc in plants is similar to magnesium (Mg) and manganese (Mn). Zinc enzyme activation is directly effective in the formation of product quantity and quality due to its effect on photosynthesis, respiration and biological membrane stability (Rout and Das, 2003). At the same time, zinc which acts on

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nitrogen (N) metabolism in plants, is effect in the formating of starch and ripening of seed (McCauley et al., 2009).

Zinc is present in the soil in the form of oxides in silicate minerals, bonded to clay minerals or in combination with organic matter. While the Zn concentration in the soil varies between 10-300 ppm, it is reported that the Zn concentration that can be taken by plants varies between 3.6-5.5 ppm (Öktüren Asri and Sönmez, 2006). Zinc toxicity in plants generally occurs above 400 ppm. Root and shoot growth of plants exposed to zinc toxicity weakens, roots become thin, young leaves curl and signs of chlorosis appear. In addition, cell growth and elongation are interrupted, cell organelles are broken down and chlorophyll synthesis is reduced (Rout and Das, 2003; Öktüren Asri and Sönmez, 2006). The zinc in the soil occurs in complex compounds that do not dissolve in time. This bonding of zinc (Zn) also affects the high soil pH. In contrast, the solubility of zinc compounds increases as the soil gains an acidic character. Zinc poisoning due to excess zinc in the soil is a very rare condition in plants. Likewise, the zinc content of plants grown in soils close to mineral deposits can be quite high. When the Zn concentration is high, the root and leaf growth of the plant is significantly weakened. In addition, the nitrogen, phosphorus and iron uptake rate of the plant decreases (Bolat and Kara, 2017).

Zinc deficiency is generally found in soils with high alkaline pH and alkaline plants with high basic character (Marschner, 1997; Bolat and Kara, 2017). In Zn deficiency, carbohydrate, protein and auxin metabolism is damaged due to the decrease in enzyme activity. The most obvious symptom of zinc deficiency in plants is a dwarf development and small leaf formation caused by deterioration of auxin metabolism and especially decrease in IAA synthesis (Kacar and Katkat, 2006; Kaya et al., 2018). In addition, chlorose-like necrosis appear between the veins of the leaves. The veins of such leaves may be green, the color of the parts between the veins are yellowish green, yellow or white. Leaf formation in plants decreases, leaves become sparse, top shoots die and early foliage is seen (Plaster, 1992).

It is reported that the amount of tryptophan in zinc deficiency in legume plants is decreased, protein synthesis is stopped and the quality of the product is adversely affected due to the accumulation of free amino acids (Yalçın and Usta, 1990; Toğay and Anlarsal, 2008).

Zinc deficiency not only limits crop yield but also lowers product quality. As a matter of fact, the lack of zinc in agricultural areas is quite common in recent years. Because, 30% of agricultural land in the world 83%, if in Turkey; It has been determined by studies that it contains less than 0.5 ppm Zn and it is reported that zinc deficiency is at significant levels in agricultural areas (Yağmur and Aydın, 2013).

In this study, the effect of increasing Cu and Zn doses and different dose application interactions on yield and yield characteristics of bean cultivars, a legume plant, was investigated. Bildirici et al. (2016) conducted different researches on the effect of heavy metals on beans in Van and its soils. They determined the relationships between some growth parameters and micro nutrients (Zn, Cu, Mn, Mg, Pb, Co, Cd and Fe). In line with this information; The aim of this study was to investigate the effects of copper (Cu) and zinc (Zn) nutrients and their interactions on the yield and yield components of bean plants grown hydroponically in the unheated greenhouse of Gevaş Vocational School of Yüzüncü Yıl University.

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Materials and Methods

This research was conducted in Turkey's Van province in 2015 and 2016 in three replications according to the Random Parcel Trial Pattern. The trial was carried out with hydroponic system in the un-heated greenhouse of Yüzüncü Yıl University in Gevaş District of Van. In the experiment, Göynük-98(Ç1) and Yakutiye-98(Ç2) bean varieties registered in 1998 were used as plant material. These varieties are among Turkey's proprietary 12 varieties of beans. It is white and coarse colored and registered to Eastern Anatolia Agricultural Research Institute (Şehirali, 1988).

Cocopeat, which is rich in organic matter, was preferred as soil material in order to see the effects of copper (Cu) and zinc (Zn) doses applied to bean cultivars. Its properties and nutrient content are given in *Table 1*.

Table 1. *Some physical and chemical properties of Cocopeat**

Soil Properties	Values
pH	5.5-6.5
Cation exchange capacity (meq/100g)	64-130
Electrical transmission (EC)	0.5-1.0 mS/cm
Compression ratio	5:1
Color	Light brown-dark brown
Appearance	Short fiber and granular
Fiber	25%
Fiber length	3-30 mm
Particle size	0.1-9 mm
Water holding capacity	9 times dry weight
Total porosity	96%
Composition (% by dry weight)	
Organic matter	94-98
Organic carbon	45-50
Lignin	65-70
Cellulose	20-30
N	0.30
K2O	0.90
P2O5	0.05
CaO	0.40
C : N rate	80 : 1

*Gül, 2008

The micro nutrients subject to the study are copper (Cu) and zinc (Zn). $CuSO_4 \cdot 5H_2O$ copper sulfate as Cu source; $ZnSO_4 \cdot 7H_2O$ zinc sulfate solution was applied homogeneously to the pots before sowing (Eren and Mert, 2016). Cu and Zn doses applied in the experiment were determined by taking into consideration the averages and upper limits reported by Lindsay (1978).

The research was established with randomized plot design with 3 replications. Before sowing the pots; 4 different levels of copper dose [0 mg kg^{-1} (Cu1), 200 mg kg^{-1} (Cu2), 400 mg kg^{-1} (Cu3), 800 mg kg^{-1} (Cu4)] in copper sulfate ($CuSO_4 \cdot 5H_2O$) format and 4 different levels of zinc dose [0 mg kg^{-1} (Zn1), 2.5 mg kg^{-1} (Zn2), 5.0 mg kg^{-1} (Zn3), 10.0 mg kg^{-1} (Zn4)] in zinc sulfate ($ZnSO_4 \cdot 7H_2O$) were determined. The main reason for the high application of copper doses is the widespread use of Cu-containing pesticides, especially in agricultural pesticides. In addition to this, to observe the possible effects of copper toxicity and the effects of copper-zinc interactions on beans

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due to the increase in the use of sewage residues such as sewage sludge as fertilizer in plant production. The experiment subjects consisted of 2 bean varieties and 4 different application doses for each element.

In this study, 540 g of cocopeat was placed in 3 liter pots with a diameter of 16.5 cm and a depth of 19.0 cm. In the experiment, seed sowing process was made 1 week after the copper application for the incubation of the copper given to the pots. Bean varieties seeds were sowed in the first year on 07.05.2015 and the second year on 10.05.2016 with one plant per flowerpot. Irrigation and fertilization of the test pots were carried out evenly and homogeneously after the exit. In the research, the macro and micro basic nutrients required by the plant were prepared as separate solutions (Buttaro et al., 2012; Di Lorenzo et al., 2013). In the preparation of the nutrient solution, Tangolar et al.'s work (2017) on the soilless culture system was used. The applied nutrient solution mixture was prepared in 150 ppm nitrogen (N) as NH_4NO_3; 20 ppm phosphorus (P) as H_3PO_4; 100 ppm potassium (K) as K_2SO_4; 15 ppm magnesium (Mg) as $MgSO_4$; 10 ppm sulfur (S) sulphate in the form of compounds; 5 ppm iron (Fe) as Fe-EDDHA; 3 ppm manganese (Mn) as $MnSO_4$ format; It was formed of three different solutions in 0.4 ppm boron (B) as H_3BO_3 and 0.05 ppm molybdenum (Mo) as $NH_4Mo_7O_{24}.4H_2O$. The plants were periodically fertilized once a week by introducing these three nutrient mixtures into the system. In both years of the study, the application of nutrient solution was started when the plants had 4-5 leaves and 1.0 mL of plant^{-1} from macro nutrient solution and 0.5 mL of plant^{-1} from micro nutrient solution were applied. The pH value of the deionized water used in this study was determined as 7.45 and electrical conductivity as 0.667.

In the experiment, harvesting was carried out on 4 October in 2015 and on 22 September in 2016 based on the physiological yellow maturity of the beans. The plants were harvested after 120-130 days of ripening period and the following characteristics were examined in comparison of the applications;

Plant height (cm), number of pods (number of plant^{-1}), number of branches (number of plant^{-1}), grain yield in the plant (g plant^{-1}), harvest index (%) and protein content (%) characteristics were measured (Yağmur and Aydın, 2013; Tangolar et al., 2017).

In the study, randomized experiment design variance analysis method was used in statistical evaluation of the effects of different doses of Cu and Zn applications on yield and yield components of plant and interactions of nutrient concentrations. In determining different groups; Duncan's (5%) Multiple Comparison Test (Düzgüneş et al., 1987), Costat and Mstatc package programs were used.

Results

Plant height (cm)

According to the data obtained at the end of the research, in year 2015, varieties, copper (Cu) doses and varieties x copper (Cu) interactions were significant; zinc (Zn), cultivar x zinc (Zn), copper x zinc and Ç x Cu x Zn interactions were statistically insignificant. In 2016, except for cultivar x copper (Cu) and Cultivar x Cu x Zn interactions, other differences between plant averages were significant (*Table 2*).

As shown in *Table 2*, the average plant height in 2015 and 2016 was obtained as higher in Göynük-98 (Ç1) cultivar (with 50.82-44.86 cm), compared to Yakutiye-98 (Ç2) cultivar. The average plant height values obtained from different copper doses in the experiment varied between 53.08-45.14 cm in 2015 and 46.19-41.39 cm in 2016.

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Table 2. *Bean varieties in the groups and averages related to the height of the plant (cm)**

		2015						2016					
		Zn Doses						Zn Doses					
Variety	**Cu Doses**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**
Ç1	**Cu1**	47.64	44.60	49.02	50.44	47.92ABC		44.14	41.43	41.19	38.80	41.39	
	Cu2	52.00	51.58	54.49	52.18	52.56AB		46.62	45.07	50.74	40.97	45.85	
	Cu3	52.50	55.10	51.87	52.83	53.08A	50.82	46.95	42.75	50.97	44.09	46.19	44.86A
	Cu4	48.14	49.16	53.71	47.90	49.73ABC		46.90	43.48	51.15	42.54	46.02	
ÇxZn Ave.		50.07	50.11	52.27	50.84			46.15B	43.18C	48.51A	41.60D		
	Cu Doses	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**
Ç2	**Cu1**	45.42	42.81	46.64	47.50	45.59C		45.24	44.85	42.54	43.96	44.15	
	Cu2	47.57	45.66	44.36	47.54	46.28BC		44.23	46.52	45.21	45.07	45.26	
	Cu3	45.14	48.13	46.82	44.78	46.22BC	45.80	42.89	47.11	46.27	46.80	45.77	44.63B
	Cu4	45.01	45.78	45.57	44.19	45.14C		40.78	45.78	40.35	46.41	43.34	
ÇxZn Ave.		45.79	45.60	45.85	46.00			43.29B	46.07A	43.59B	45.56A		
Zn Ave.		47.93	47.85	49.06	48.42			44.72B	44.61BC	46.05A	45.56C		
Yıl Ave.		48.31A						45.41 B					
		Zn1	**Zn2**	**Zn3**	**Zn4**	**Cu Ave.**		**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Cu Ave..**	
Cu x Zn	**Cu1**	45.42	42.81	46.64	47.50	46.75B		44.69bc	43.14c	41.87d	41.38d	42.77B	
	Cu2	47.57	45.66	44.36	47.54	49.42A		45.43b	45.80b	47.98ab	43.02c	45.55A	
	Cu3	45.14	48.13	46.82	44.78	49.65A		44.92bc	44.93bc	48.62a	45.45b	45.98A	
	Cu4	45.01	45.78	45.57	44.19	47.43B		43.84c	44.63bc	45.75b	44.48bc	44.67A	
LSD 0.05		1.51						1.24					
C.V (%)		5.43						4.72					

*The difference between the averages indicated by the same letters is not significant at 5% level. Cu: Copper Dose, Zn: Zinc Dose, Ç1: Göynük-98, Ç2: Yakutiye-98, Avg.: Average, ÇxCu: Variety x Copper Dose Interaction, Ç x Zn: Variety x Zinc Dose Interaction, Cu x Zn: Copper x Zinc Dose Interaction

According to the results of the research, the plant height in the averages of in 2015 and 2016 and both year averages was obtained from the applications of 400 mg kg^{-1} Cu3 applied, respectively to Göynük-98 variety with 53.08-46.19 cm.

In the first year of the experiment, the lowest plant height was determined as 45.14 cm with 800 mg kg^{-1} Cu4 dose applied to Yakutiye-98 cultivar. In the second year, the low plant height was 41.39 cm and it was obtained from Göynük-98 variety without copper application.

It was determined that the plant height value was higher in plots with 5.0 mg kg^{-1} zinc dose applied to Göynük-98 cultivar (52.27-48.51 cm) in both years of the experiment. The shortest plant length was measured in Yakutiye-98 cultivar, where a dosage of 41.60 cm and 2.5 mg kg^{-1} zinc was applied. In similar studies on legumes, they reported that increased zinc fertilization increased plant height (Togay and Anlarsal, 2008).

In terms of zinc x copper doses applied in the study, the interaction effect between the doses in 2015 was found to be statistically insignificant. In 2016, the effect of the interaction between 5.0 mg kg^{-1} zinc dose and 800 mg kg^{-1} copper doses applied to Göynük-98 bean variety was found to be statistically significant in terms of plant height (51.15 cm) (*Table 2*).

It is known in the studies on legumes that increasing doses of zinc fertilization increases the plant height to a certain extent. However, this difference between years is

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thought to be due to the effect of climate factors as well as the usefulness of copper applied. As a matter of fact, the expected benefit from fertilizing in terms of yield and quality in crop production depends on the application of the right fertilizer source at the right time, with the right methods and appropriate quantities.

Number of pods (pieces / plant)

According to the results of the experiment, there was a difference between the number of pods between the years. On average number of pods in 2015 copper and zinc doses, varieties x copper and varieties x zinc dose interactions were significant, varieties, copper x zinc and varieties x copper x zinc interactions were statistically insignificant. In 2016, varieties, copper, zinc, copper x zinc interactions were found to be statistically significant.

The average number of pods obtained as a result of the research was counted as 14.12 in the first year and 9.31 in the second year. According to the results obtained, the average number of pods in years for Göynük-98 variety, was respectively, 14.04-9.93 in the other varieties of Yakutiye-98 variety was determined as 14.20-8.71 (*Table 3*).

Table 3. *Averages and formed groups on number of pods in bean varieties (pieces / plant)**

		2015						**2016**					
		Zn Doses						**Zn Doses**					
Variety	**Cu Doses**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**
Ç1	**Cu1**	10.46	12.66	15.61	13.88	13.15AB		8.08	9.18	8.81	8.96	8.76	
	Cu2	12.53	15.21	14.71	15.15	14.40AB		8.81	9.73	10.03	12.55	10.28	
	Cu3	13.18	13.34	15.35	15.48	14.34AB	14.04	10.01	10.34	11.62	10.27	10.55	9.93A
	Cu4	14.04	12.00	15.55	15.45	14.26AB		10.28	11.30	10.02	8.80	10.10	
ÇxZn Ave.		12.55D	13.30C	15.31A	14.99B			9.30B	10.13A	10.12A	10.15A		
	Cu Doses	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**
Ç2	**Cu1**	11.80	12.67	14.24	11.57	12.57B		7.77	8.25	7.96	7.05	7.76	
	Cu2	14.76	12.12	15.25	16.57	14.68AB		9.12	8.79	10.07	10.12	9.52	
	Cu3	16.58	14.78	17.37	16.47	16.30A	14.20	8.29	10.95	9.28	7.71	9.06	8.71B
	Cu4	13.91	11.96	13.79	13.34	13.25AB		7.74	9.88	8.39	7.93	8.48	
ÇxZn Ave.		14.26B	12.88C	15.16A	14.49B			8.23B	9.47A	8.93AB	8.19B		
Zn Ave.		13.41B	13.09B	15.23A	14.74A			8.76B	9.80A	9.52AB	9.17B		
Yıl Ave.		14.12A						9.31 B					
		Zn1	**Zn2**	**Zn3**	**Zn4**	**Cu Ave.**		**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Cu Ave.**	
Cu x Zn	**Cu1**	11.13	12.67	14.93	12.73	12.86D		7.93d	8.72cd	8.39cd	8.01d	8.26B	
	Cu2	13.65	13.67	14.98	15.86	14.54B		8.97cd	9.26bc	10.05b	11.34a	9.91A	
	Cu3	14.88	14.06	16.36	15.98	15.32A		9.15bc	10.63ab	10.45ab	8.99c	9.80A	
	Cu4	13.98	11.98	14.67	14.40	13.76C		9.01c	10.59ab	9.21bc	8.35cd	9.29A	
LSD $_{0.05}$		0.80						0.73					
C.V (%)		9.88						13.64					

*The difference between the averages indicated by the same letters is not significant at 5% level. Cu: Copper Dose, Zn: Zinc Dose, Ç1: Göynük-98, Ç2: Yakutiye-98, Avg.: Average, ÇxCu: Variety x Copper Dose Interaction, Ç x Zn: Variety x Zinc Dose Interaction, Cu x Zn: Copper x Zinc Dose Interaction

According to the data obtained, the interaction of varieties x copper doses in the first year was statistically significant and the second year was insignificant on the average

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number of pods. The highest number of broad beans was obtained from Yakutiye-98 bean cultivars with 16.30 doses of 400 mg kg^{-1} Cu3, and the lowest value was obtained from 0 mg Cu kg^{-1} Cu1 control dose in Yakutiye-98 cultivars with 12.57 units. According to these results, increasing doses of copper increased the number of pods per plant up to a certain point and then decreased.

In the study, the interaction of copper x zinc doses on the average number of pods was found statistically insignificant in the first year and significant in the second year. The highest number of pods was obtained in the first year with 16.36 units of 400 mg Cu kg^{-1} Cu3 and 5.0 mg Zn kg^{-1} Zn3. The lowest value was obtained from 0 doses of both application doses with 11.13 units (*Table 3*). In the second year of the experiment, the highest number of pods was obtained from 11.34 units of 200 mg Cu kg^{-1} Cu2 and 10.0 mg Zn kg^{-1} Zn4. The lowest value was determined in doses of 7.93 with 0 (*Table 3*). According to these results, increased zinc doses at low copper doses increased the number of pods per plant. It is known that where copper and zinc fertilizer are used together, copper x zinc decreases the efficiency of use and causes decrease in yield and quality.

Number of branches (pieces / plant)

In 2015, it was found that the number of branches, beans, zinc doses, varieties x zinc doses and copper x zinc doses interactions on the average number of branches were statistically significant. In the second year of the experiment, the effect of all application doses and interactions on the average number of branches in bean cultivars was found to be statistically insignificant (*Table 4*).

Table 4. *Groups and averages of the number of branches in bean varieties (pieces / plant)**

		2015						2016					
		Zn Doses						Zn Doses					
Variety	**Cu Doses**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave**
Ç1	**Cu1**	6.27	5.98	6.37	5.11	5.93		4.79	4.32	4.86	4.99	4.74	
	Cu2	4.77	6.59	6.65	6.42	6.11		5.41	4.58	4.64	4.10	4.68	
	Cu3	5.12	5.35	5.60	6.33	5.60	5.83B	4.65	4.14	4.26	4.66	4.43	4.58
	Cu4	5.96	5.74	6.14	4.94	5.70		4.49	4.10	4.79	4.53	4.48	
ÇxZn Ave.		5.53D	5.92B	6.19A	5.70C			4.84	4.29	4.64	4.57		
	Cu Doses	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**
Ç2	**Cu1**	7.10	7.74	7.55	6.95	7.34		4.83	4.54	4.84	4.75	4.74	
	Cu2	6.03	7.20	6.05	7.64	6.73		4.93	5.18	5.22	5.41	5.19	
	Cu3	6.52	8.67	6.45	7.42	7.27	7.12A	5.27	5.32	4.96	4.18	4.93	4.80
	Cu4	6.99	7.63	7.30	6.74	7.17		4.55	4.37	4.36	4.16	4.36	
ÇxZn	**Ave.**	6.66C	7.81A	6.84C	7.19B			4.90	4.84	4.85	4.63		
Zn Ave.		6.10C	6.86A	6.51AB	6.44BC			4.87	4.57	4.74	4.60		
Yıl Ave.		6.48A						4.69B					
		Zn1	**Zn2**	**Zn3**	**Zn4**	**Cu Ave.**		**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Cu Ave.**	
Cu x Zn	**Cu1**	6.69b	6.86ab	6.96ab	6.03cd	6.63b		4.81	4.43	4.85	4.87	4.74	
	Cu2	5.40de	6.90ab	6.35c	7.03a	6.42b		5.17	4.88	4.93	4.76	4.93	
	Cu3	5.82d	7.01a	6.03cd	6.88ab	6.43b		4.96	4.73	4.61	4.42	4.68	
	Cu4	6.48b	6.69b	6.72ab	5.84d	6.43b		4.52	4.24	4.58	4.35	4.42	
LSD 0.05		0.40						0.34					
C.V (%)		10.79						13.01					

*The difference between the averages indicated by the same letters is not significant at 5% level. Cu: Copper Dose, Zn: Zinc Dose, Ç1: Göynük-98, Ç2: Yakutiye-98, Avg.: Average, ÇxCu: Variety x Copper Dose Interaction, Ç x Zn: Variety x Zinc Dose Interaction, Cu x Zn: Copper x Zinc Dose Interaction

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According to the results obtained in the experiment, the average number of branches was 6.48 in the first year and 4.69 in the second year. The number of branches among the bean varieties was obtained from 5.83-4.58 plant^{-1} and Göynük-98 varieties, respectively. In the Yakutiye-98 variety, a higher number (7.12-4.80) of branching was detected (*Table 4*). According to the results obtained on the average number of branches in the first year Ç x Zn interaction was statistically significant, the second year was found to be insignificant. According to the results obtained from the experiment, the highest average branch number was obtained from 2.5 mg kg^{-1} Zn2 dose applied to Yakutiye-98 cultivar. The lowest value was obtained from the control (0 dose) application of Göynük-98 variety with 5.53 units (*Table 4*).

As shown in *Table 4*, the effect of Cu x Zn interaction on the mean number of branches was significant ($p<0.01$). The highest average number of branches was obtained from 7.03 Zn4 dose of 200 mg kg^{-1} Cu2 x 10.0 mg kg^{-1}. The lowest value was measured with 5.40 units of 200 mg kg^{-1} Cu2 x 0 mg kg^{-1} Zn1 control dose.

Harvest index (%)

It was determined that the factors other than cultivars, copper doses, varieties x copper dose interactions were insignificant on the harvest index of bean cultivars in 2015.

In 2016, the effect of varieties, copper and zinc doses, cultivar x zinc and Ç x Cu x Zn interactions on harvest index averages were found to be statistically significant (*Table 5*).

Table 5. *Groups and averages of harvest index in bean varieties(%)**

		2015						**2016**					
		Zn Doses						**Zn Doses**					
Variety	**Cu Doses**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu Ave.**	**Ç. Ave.**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu Ave.**	**Ç. Ave.**
Ç1	**Cu1**	34.51	37.12	39.39	36.18	36.80C		37.51cd	37.90c	38.22c	39.40bc	38.26	
	Cu2	40.65	39.54	40.54	43.40	41.03A		38.52c	42.49a	41.90ab	40.66b	40.89	
	Cu3	40.28	41.69	40.56	40.70	40.81B	38.83B	39.76bc	41.26ab	39.66bc	39.07bc	39.94	39.38B
	Cu4	39.21	35.60	37.27	34.59	36.67C		34.85e	40.58b	41.64ab	36.61d	38.42	
ÇxZn Ave.		38.66	38.49	39.44	38.72			37.66C	40.56A	40.36A	38.94B		
	Cu Doses	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**
Ç2	**Cu1**	44.25	42.44	43.68	42.04	43.10C		41.73cd	44.37b	43.18	42.79c	43.02	
	Cu2	48.03	40.92	45.44	45.21	44.90A		45.20ab	44.08b	44.57b	45.99ab	44.96	
	Cu3	44.72	42.43	45.39	43.34	43.97B	44.03A	45.51ab	43.46bc	46.56a	46.52a	45.51	44.07A
	Cu4	43.24	46.42	47.05	39.94	44.16AB		43.30bc	42.60c	41.97cd	43.30bc	42.79	
ÇxZn Ave.		45.06	43.05	45.39	42.63			43.94B	43.63B	44.07A	44.65A		
Zn Ave.		41.86	40.77	42.42	40.68			40.80B	42.09A	42.21A	41.79AB		
Yıl Ave.		41.43A						41.72B					
		Zn1	**Zn2**	**Zn3**	**Zn4**	**Cu Ave.**		**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Cu Ave.**	
Cu x Zn	**Cu1**	39.38	39.78	41.54	39.11	39.95B		39.62	41.14	40.70	41.10	40.64B	
	Cu2	44.34	40.23	42.99	44.31	42.97A		41.86	43.29	43.24	43.33	42.93A	
	Cu3	42.50	42.06	42.98	42.02	42.39A		42.64	42.36	43.11	42.80	42.73A	
	Cu4	41.23	41.01	42.16	37.27	40.42B		39.08	41.59	41.81	39.96	40.61B	
LSD $_{0.05}$		1.53						1.02					
C.V (%)		6.42						4.26					

*The difference between the averages indicated by the same letters is not significant at 5% level. Cu: Copper Dose, Zn: Zinc Dose, Ç1: Göynük-98, Ç2: Yakutiye-98, Avg.: Average, ÇxCu: Variety x Copper Dose Interaction, Ç x Zn: Variety x Zinc Dose Interaction, Cu x Zn: Copper x Zinc Dose Interaction

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According to the results obtained at the end of the research, harvest index was found to be 38.83-39.38% in Ç1 (Göynük-98) and 44.03-44.07% in Ç2 (Yakutiye-98). In this research, the highest harvest index average was obtained from Ç2 according to the results of both years. It is thought that this difference, which occurred a little between the years, is due to environmental factors, genotype and cultural practices.

In the study, average harvest index values obtained from different copper doses applications varied between 42.97-39.95% in 2015 and 42.93-40.6% in 2016 (*Table 5*). According to the results of the study, the highest harvest index in 2015 and 2016 and the average of both years was obtained from 200 mg kg^{-1} Cu2 dose applied to Ç2 (Yakutiye-98) with 44.90-45.51%, respectively. In the first year of the experiment, the lowest harvest index value was found to be 800 mg Cu kg^{-1} Cu4 administered to Ç1 with 36.67%. In the second year, the lowest harvest index was obtained from the parcel without copper applied to Ç1 with 38.26%. Eren and Mert (2016) investigated the effect of increasing Cu applications on the growth and development of plants and found that the lowest plant dry weight of the plants was 2.28 g $plant^{-1}$ and 800 mg Cu kg^{-1} application and control application.

As it can be seen in *Table 5*, zinc (Zn) and Ç x Zn dose interactions on the average harvest index were found to be statistically insignificant and significant in the second year. According to the results obtained from the experiment, the highest harvest index was obtained from the dose of 5.0 mg kg^{-1} Zn3 applied to Ç2 (Yakutiye-98) with 42.21%. The lowest value was obtained from control (0 dose) application of Ç1 (Göynük-98) with 37.66% (*Table 5*). In the study, it was observed that increasing the dose of Çx Zn increased the harvest index up to a certain point. Taban and Alpaslan (1996) from the soil to the corn plant; in a similar study by applying 0, 2.5, 5.0 and 10.0 mg Zn kg^{-1}, the highest increase in dry weight (67.3% increase) was obtained from the dose of 5.0 mg Zn kg^{-1} applied to flowerpot-1 with 14.96 g.

According to the results, the effect of cultivars x Cu x Zn interactions on the harvest index was statistically insignificant in the first year and was significant in the second year. The average harvest index values were 34.51-48.03% in 2015 and 34.85-46.56% in 2016 (*Table 5*). In the second year, the highest harvest index was obtained from interaction of doses of 400 mg Cu kg^{-1} Cu3 x 5.0 mg Zn kg^{-1} Zn3 applied to Yakutiye-98 cultivar with 46.56% (Z2 x Cu3 x Zn3). The lowest value of 34.85% Göynük-98 variety was obtained from the application of 800 mg kg^{-1} Cu4 x Zn1 control (0 dose) (*Table 5*).

Grain yield in the plant (g / plant)

On the average seed yield in bean plant of different phosphorus and zinc doses in 2015 and 2016 research years; cultivar, copper, zinc, cultivar x copper, cultivar x zinc, copper x zinc and cultivar x copper x zinc interactions were found to be statistically significant (*Table 6*). Average seed yields in per plant obtained at the end of the experiment were measured as 23.49 g $plant^{-1}$ in the first year and 18.72 g $plant^{-1}$ in the second year.

According to the results, average seed yield of Göynük-98 bean cultivar was 19.35-16.87 g $plant^{-1}$ over the years, while it was 27.63-20.58 g $plant^{-1}$ in Yakutiye-98 cultivar. Düzdemir and Akdağ (2001) in their study; reported that the mean seed yield in the plant was between 10.20-27.40 g $plant^{-1}$. In the study of by Bildirici and Baran (2018) in under the ecological conditions of Van-Gevaş, the seed yields of Akman-98 and Göynük-98 varieties were determined as 9.82-13.44 g $plant^{-1}$, respectively. Seed

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yield in beans shows dependence on other genetic-based variations, especially earliness in different environmental conditions.

Table 6. *Groups and averages of grain yield in bean varieties (g /plant)**

		2015						**2016**					
		Zn Doses						**Zn Doses**					
Variety	**Cu Dose**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu Ave.**	**Ç. Ave.**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu Ave.**	**Ç. Ave.**
Ç1	**Cu1**	12.02fg	19.15bc	18.65bc	21.54ab	17.84D		15.97c	18.45ab	14.65cd	17.15bc	16.55B	
	Cu2	20.17b	22.40a	21.57ab	19.83b	21.00A		17.92b	18.94ab	19.38a	19.50a	18.93A	
	Cu3	17.02cd	17.00cd	21.11ab	22.58a	19.43B	19.35B	18.50ab	19.58a	17.90b	17.19bc	18.30A	16.87B
	Cu4	21.43ab	18.19c	18.18c	18.76bc	19.14C		13.62d	18.24ab	12.07de	10.85ef	13.69C	
Ç x Zn Ave.		17.66 D	19.20 C	19.88 B	20.68 A			16.50 B	18.79 A	16.00 C	16.17 C		
	Cu Dose	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu Ave.**	**Ç. Ave.**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu Ave.**	**Ç. Ave.**
Ç2	**Cu1**	21.51f	19.35g	27.24de	23.65de	260.13B		12.18cd	16.19bc	20.74b	21.94ab	17.76C	
	Cu2	28.12d	30.94b	33.83ab	31.27ab	343.93A		17.86bc	24.33ab	28.45a	24.69a	23.83A	
	Cu3	29.36c	29.21c	36.32a	31.11c	342.19A	27.63A	13.88c	26.06a	20.28ab	20.28b	20.63B	20.58A
	Cu4	22.69f	23.61ef	25.01e	24.51de	269.64B		16.47bc	21.80ab	22.08b	22.08ab	20.09B	
Ç x Zn Ave.		25.42	25.78	30.61	28.73			15.10	22.09	22.87	22.25		
Zn Ave.		21.54C	22.48B	25.24A	24.71A			15.80C	20.45A	19.43AB	19.21B		
Year Ave.		23.49						18.72					
		Zn1	**Zn2**	**Zn3**	**Zn4**	**Cu Ave.**		**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Cu Ave.**	
Cu x Zn	**Cu1**	16.76fg	19.25f	22.94cd	20.74c	20.74D		14.08e	17.32cd	17.69cd	19.55bc	17.16C	
	Cu2	24.15c	26.67b	27.71ab	27.71b	26.13A		17.89cd	21.64ab	23.92a	22.10ab	21.39A	
	Cu3	23.19cd	23.10cd	28.72a	28.72b	25.27B		16.19d	22.82a	20.09b	18.74c	19.46B	
	Cu4	22.06d	20.90de	21.60d	21.60cd	21.83C		15.05de	20.02b	16.03d	16.47d	16.89C	
LSD 0.05		8.27						11.62					
C.V (%)		5.56						9.79					

*The difference between the averages indicated by the same letters is not significant at 5% level. Cu: Copper Dose, Zn: Zinc Dose, Ç1: Göynük-98, Ç2: Yakutiye-98, Avg.: Average, ÇxCu: Variety x Copper Dose Interaction, Ç x Zn: Variety x Zinc Dose Interaction, Cu x Zn: Copper x Zinc Dose Interaction

The effects of copper fertilizer on average seed yield in the plant of beans were found to be statistically significant. The highest seed yield was obtained from the doses of 31.27-23.83 g plant^{-1} and 200 mg kg^{-1} Cu2 in Yakutiye-98 cultivars in both years of the experiment. The lowest value for years 17.84-13.69 g plant^{-1} and 0 fertilizer dose of copper and copper (800 mg kg^{-1} Cu4) dose was determined in the parcels applied (*Table 6*). As seen in *Table 6*, the effect of zinc doses on average seed yields of bean cultivars was found to be significant. Average highest seed yields obtained in the experiment over the years for Yakutiye-98 bean cultivar 30.61-22.87 g plant^{-1} and 5.0 mg Zn kg^{-1} Zn3 dose was obtained from the application. The lowest yield values (25.42-15.10 g plant^{-1}) in 0 zinc dose (Zn1) was measured in Göynük-98 bean cultivar.

The effect of copper and zinc doses on the average seed yield of beans was significant ($p < 0.01$). The highest average seed yield in both years of the study was obtained from 28.72-23.92 g plant^{-1}, 200-400 mg kg^{-1} copper and 5.0 mg kg^{-1} Zn3 zinc, respectively. The lowest yield value in two years 16.76-14.08 g plant^{-1}, respectively with 0 copper and zinc fertilizer dose was obtained from parcels (*Table 6*). The effect of copper and zinc fertilizer doses on average seed yield of bean cultivars was found to be statistically significant in both years. The highest average seed yield was obtained from

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Yakutiye-98 cultivar in 36.32-28.45 g plant^{-1} and 400 mg kg^{-1} Copper (Cu3) x 5.0 mg kg^{-1} Zinc (Zn3) application in two years. Low values 12.01-10.85 g plant^{-1} were obtained from Ç1 (Göynük-98) variety, in the cases of 0 dose and 800 mg kg^{-1} copper-zinc dose (Cu4 x Zn4) applications (*Table 6*).

Crude protein content (%)

As a result of the research, the interactions of the varieties, varieties x zinc, varieties x copper doses and copper x zinc doses were found to be statistically significant on the crude protein content of the grains obtained. Protein ratio by years are as follows: while Göynük-98 variety was obtained with 21.93-22.01%, 22.06-21.45% protein ratios were obtained from Yakutiye-98 variety (*Table 7*).

Table 7. *Groups and averages of crude protein ratios in bean varieties(%)**

		2015						2016					
		Zn Doses						Zn Doses					
Variety	**Cu Doses**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**
Ç1	**Cu1**	19.74	22.89	22.94	20.43	21.50		20.75	22.87	22.56	20.41	21.65	
	Cu2	21.29	22.48	24.16	20.92	22.21		22.66	22.45	23.35	21.05	22.38	
	Cu3	20.36	23.55	23.06	22.75	22.43	21.93	20.71	23.52	22.61	22.74	22.40	22.01A
	Cu4	20.50	21.83	22.82	21.23	21.60		20.72	21.86	22.44	21.47	21.62	
ÇxZn Ave.		20.47D	22.69B	23.25A	21.33C			21.21B	22.68A	22.74A	21.42B		
	Cu Doses	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**	**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Ç x Cu. Ave.**	**Ç. Ave.**
Ç2	**Cu1**	21.99	22.88	22.62	21.15	22.16		20.99	22.04	22.25	22.03	21.83	
	Cu2	21.81	22.68	22.14	22.43	22.27		21.76	21.93	21.76	22.21	21.92	
	Cu3	20.75	21.64	22.79	23.67	22.21	22.06	20.63	21.64	21.61	21.37	21.31	21.45B
	Cu4	20.41	21.26	21.93	22.84	21.61		20.40	20.37	20.81	21.43	20.75	
ÇxZn Ave.		21.24B	22.12A	22.37A	22.52A			20.95B	21.50A	21.61A	21.76A		
Zn Ave.		20.86C	22.40AB	22.81A	21.93B			21.08C	22.09AB	22.17A	21.59BC		
Yıl Ave.		22.00						21.73					
		Zn1	**Zn2**	**Zn3**	**Zn4**	**Cu Ave.**		**Zn1**	**Zn2**	**Zn3**	**Zn4**	**Cu Ave.**	
Cu x Zn	**Cu1**	20.87bc	22.89ab	22.78ab	20.79bc	21.83AB		20.87	22.46	22.41	21.22	21.74AB	
	Cu2	21.55b	22.58ab	23.15a	21.68b	22.24A		22.21	22.19	22.56	21.63	22.15A	
	Cu3	20.56bc	22.60ab	22.93ab	23.21a	22.32A		20.67	22.58	22.11	22.06	21.85A	
	Cu4	20.46bc	21.55b	22.38ab	22.04ab	21.60B		20.56	21.12	21.63	21.45	21.19B	
LSD 0.05		0.51						0.54					
C.V (%)		4.02						4.34					

*The difference between the averages indicated by the same letters is not significant at 5% level. Cu: Copper Dose, Zn: Zinc Dose, Ç1: Göynük-98, Ç2: Yakutiye-98, Avg.: Average, ÇxCu: Variety x Copper Dose Interaction, Ç x Zn: Variety x Zinc Dose Interaction, Cu x Zn: Copper x Zinc Dose Interaction

The effect of different zinc doses on protein ratios in beans was found to be statistically significant in both years. The highest crude protein content by years with 5.0 mg Zn kg^{-1} was obtained from Göynük-98 bean cultivar with 23.25-22.74%, the lowest values were obtained from 0 dose application of 20.47-20.95%.

As shown in *Table 7*, the effect of copper doses on average crude protein ratios in beans was significant in 2015-16 ($p < 0.05$). The highest crude protein content was obtained from 200-400 mg kg^{-1} copper applications with 22.15-22.32%. The lowest value was found to be 800 mg Cu kg^{-1} copper (Cu4) with 21.19-21.60% (*Table 7*).

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Discussion

In addition, plant height values were lower in both cultivars in the second year than in the first year. According to the first year of the experiment, due to the high average temperature and the lack of moisture due to the decrease in the time from the output to ripening caused the plant height values to decrease. It is thought that this difference is caused by climate in terms of plant height values between years (Elkoca and Kantar, 2004). It is thought that this difference between the years is due to the effect of climate factors as well as the usefulness of the applied copper. Çopur and Sarı (2012) in the study of the effect of $CuSO_4.5H_2O$ on the growth of cucumber seedlings concluded that applications are significant in terms of seedling length. Seedling height of 9.53 cm of the highest seedlings with copper sulfate 4000 + 4000 mg / l were detected in the application. Zengin and Munzuroğlu (2004) investigated the effects of mercury, copper, cadmium and lead on the amount of growth hormone cytokine in bean seedlings. In their study, control seedlings and seedlings grown in 0.1, 0.2 and 0.3 mM $CuCl_2$ solutions were measured the cytokine content of 1.83x10-7, 4.42x10-7, 3.77x10-7, 3.66x10-7 and 3.55x10-7 M, respectively. They stated that growth is supported up to a point, increasing the dose of copper decreases the cytokinin level of the seedlings and this situation occurs due to increase in copper concentration. These results are consistent with our findings.

Yağmur and Aydın (2013) applied 10, 20 and 30 mg Zn kg-1 (ZnSO4.7H2O) in the soil and in addition 0.1%, 0.2% and 0.3% ZnSO4.7H2O solution to the leaves in lettuce cultivation. The highest plant height (22.25 cm and 21.10 cm) was obtained from applications of 20 mg kg-1 zinc to the soil and 0.2% zinc to the leaves. The results obtained support our study.

Elkoca and Kantar (2004), in a similar study conducted by the number of pods between 3.5-4.2 on this variety showed a wide variation according to the variety and lines. Sönmez et al. (2006b) applied 1000 and 2000 mg Cu kg^{-1} yield in tomatoes grown in the greenhouse yield, fruit number, dry root weight and plant height were reported to decrease with the amount of Cu in the soil. This study supports our findings. In a similar study Yağmur and Aydın (2013) applied Zn in the form of 0.1%, 0.2% and 0.3% $ZnSO_4.7H_2O$ solution from the leaf in addition to 10, 20 and 30 mg Zn kg^{-1} ($ZnSO_4.7H_2O$) doses. As a result of the research, they were obtained the highest plant height (22.25 cm and 21.10 cm) by applying 20 mg kg^{-1} zinc to the soil and 0.2% Zinc dose to the leaf. The results obtained from these studies are in parallel with the findings of our research.

It is thought that this difference in average number of branches over the years is due to the differences in the amount of humidity and temperature in the greenhouse as well as genetic factors (Elkoca and Kantar, 2004). Babagil et al. (2011) stated that they measured the maximum number of branches in 3.1 beans-1 and Yakutiye-98 cultivars in their study with 6 bean cultivars under Erzurum conditions. Kumar et al. (1993) reported that zinc doses applied to the soil between 0 and 5 kg da^{-1} increase the yield and decrease at the next doses. Similar results have been obtained in many studies (Azad et al., 1993; Yağmur and Aydın, 2013). Unlike nitrogenous fertilizers, the effect of micro nutrients on the number of branches depends on the environment and genetic structure. In the study, increasing dose of Cu x Zn increased the number of pods per plant up to a certain point. Wang et al. (2016) in a similar study conducted in China on Indian beans; reported that Cu and Zn interactions applied at low concentrations in the soil caused a slight increase in the growth of the plant, whereas high concentrations

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showed a significant decrease in plants height and biomass. We can assume that the interaction of Cu and Zn is clear. Zn, Cd and Cu interactions related to the similar results have been reported about the interactions (Chizzola and Mitteregger, 2005; Chaoui et al., 2017).

Gangwar and Singh (1986), in their studies of zinc fertilizer increases the rate of harvest index rate has been reported that the maximum rate is taken from the applied foliar fertilizer. Azad et al. (1993) reported that zinc fertilizers increased the harvest index rate up to a certain dose and then decreased. In this study, it was observed that zinc fertilizer increased the harvest index rate up to 2.5 and 5.0 mg Zn kg^{-1} and then started to decrease. MacFarlane and Burchett (2002), in their study applied an increasing doses from 100 µg Cu g^{-1} to 400 µg Cu g^{-1} reported a reduction in total plant biomass and a decline in root growth. Therefore, similar results were obtained in this study as in many fertilization studies (Pholsen and Sormsungnoen, 2005; Barros et al., 2007). According to some other studies, it has been reported that the green parts and grain contents of wheat plant increase with Zn application and this increase varies according to varieties (Helaloğlu et al., 1997). Many of these studies support our findings.

It is known that there is an antagonistic effect between Cu and Zn ions (Aktaş, 1991; Chizzola and Mitteregger, 2005). Wang et al. (2016) stated that Cu and Zn interactions applied at low concentrations in the soil caused a slight increase in the growth of the plant, whereas a significant decrease in plant height and biomass was observed in high concentrations. The most important factor in determining fate of crop production is undoubtedly the growing conditions and climate factors. It is thought that this difference between years is mainly due to the fact that the average temperature and distribution in the first year(21.3 ^{o}C) is higher compared to the second year (17.90 ^{o}C). In addition, the bean is very sensitive to the water balance in the soil during the flowering period. It has been reported that fluctuations in this period cause 20% yield losses in grain yield. In the first year of the research, the average temperature has been identified to be higher than the second year, especially during the flowering and pollination periods (Elkoca and Kantar, 2004). Seed yield in bean plants shows dependence on earliness of different environmental conditions in genetic variations. In the study, it was observed that the average seed yield of varieties increased up to 200 mg kg^{-1} copper dose in parallel with the increasing copper doses, and it caused decreases in seed yield in subsequent doses (Wang et al., 2016). Sönmez et al. (2006b) 1000 and 2000 mg Cu kg^{-1} applied to the soil in greenhouse grown tomatoes; reported that yield, fruit number, dry root weight and plant height decreased with high Cu doses such as. This study supports our findings. It is estimated that the difference between the first and second year zinc doses of the study is due to the fact that copper inhibits the zinc uptake more than the second year.

In the first year, it is estimated that fertilizers are used more beneficially due to the favorable conditions of the average temperature and climate (Taban et al., 1997; Toğay and Anlarsal, 2008). In studies where copper and zinc fertilizer are used together, it is known that copper x zinc increases the efficiency of use, decreases soil pH, increases total N and P intake and has a positive effect on yield and quality (Sönmez et al., 2006a). In this study, it has been found that increasing doses of Ç x Cu x Zn increases the seed yield up to a certain point (Wang et al., 2016). Sonmez et al. (2006a) found that the effect of Cu applications on soil, which Zn contents was increased by 5% was significant. This study in bean is in agreement with the results of many researchers.

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In many studies, it has been determined that the protein content of bean grains varies between 17.40% and 28.00% according to the varieties and applications. It was stated that bacterial applications, especially nitrogen fertilization, increased this rate (Tajini et al., 2012). The effect of zinc fertilizer on crude protein content was found to be important depending on environmental and genotypic factors. Similar results have been obtained in other studies conducted on legume plants (Toğay and Anlarsal, 2008). Zinc is an active element in biochemical processes as well as has a biological interaction. When zinc (Zn^{++}) is used together with copper (Cu^{++}), an increase in uptake occurs by plants (Sönmez et al., 2006a; Wang et al., 2016). According to some other studies; Leaf and soil zinc sulphate applications to watermelon, grapes, wheat, lentils, spinach have been found to have a positive effect on quality components yield, yield components of different crop plants, vegetative growth and development (Kaya et al., 20018).

Conclusion

In this study carried out as a greenhouse experiment in Van-Gevaş ecological conditions, the effect of different copper-zinc dose and applications and interactions on the yield and yield characteristics of dry bean cultivars grown in soilless systems were investigated. Although these factors have changed over the years, they have provided important information in terms of yield and yield components. The use of zinc at increasing copper doses and the decrease in efficacy and it has been seen decline in yield and quality parameters too. Soil analysis should be done before sowing in culture plants, especially legumes, in our province where zinc deficiency is seen too much. Based on these results, in case of deficiency, copper fertilization between 2.5-5.0 mg Zn kg^{-1} zinc and 200-400 mg Cu kg^{-1} can be performed. It is known that copper zinc increases usage efficiency, decreases soil pH, increases total N and intake P contents, and has a positive effect on yield and quality. However, it should not be ignored that it may have toxic effects in overuse. In general, the interaction of copper-zinc concentrations examined did not reach the degree of toxic effect in the plant.

As a result, co-administration of copper-zinc interactions, 400 mg kg^{-1} Cu and 5.0 mg kg^{-1} Zn doses resulted in an increase in yield and yield parameters in bean compared to the separate administration of these doses and was found to be statistically significant at 1% level. It is thought that this study will contribute to the new studies to reduce the yield and quality losses that may occur due to Zn deficiency, Cu excess or interactions in agricultural soils.

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